FUEL PUMP CHANNEL

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Field of the Invention

The claimed invention relates to a rotary pump. In particular, the invention relates to a fuel pump having a channel with improved operating characteristics.

Background of the Invention

Regenerative fuel pumps are used in vehicles to pump fuel from a fuel tank through a fuel handling system to the engine of the vehicle. Fuel pumps typically include a driven ring impeller that rotates within a pump housing. The impeller has an upstream side and a downstream side. The pump housing includes a cover that is positioned adjacent the upstream side of the impeller and a body that is positioned adjacent the downstream side of the impeller. The pump housing serves as the outer shell of the fuel pump that houses the cover, impeller, body and other pump parts.

The ring impeller has vanes, which are bounded by annular channels defined in the housing. The channels are positioned at the upstream and downstream sides of the impeller vanes on the cover and body, respectively. The channel on the cover side of the impeller provides fuel to the impeller while the channel on the body side expels fuel from the impeller. Primary vortices are formed within each channel by the pumping action of the impeller. The primary vortices are propelled to the ends of each channel before being expelled through the fuel outlet in the body. Pumping losses occur when secondary vortices develop in the flow channels in those areas of the channel that do not conform to the shape of the primary vortices.

Summary

In a first embodiment of the invention, a pump includes a pump housing, an inlet opening, an outlet opening, and an impeller. The pump housing has an axis and includes a cover having a face surface and a body having a face surface positioned about the axis. An arcuate channel is defined in the face surface of the cover and an arcuate channel is defined in the face surface of the body. The arcuate channel has a length extending at least partially circumferentially about the axis. The inlet opening extends through the cover and is coupled

to the cover channel. An outlet opening extends through the body and is coupled to the body channel. An impeller is positioned between the face surface of the cover and the face surface of the body. At least one of the cover channel or the body channel has a cross-sectional shape along at least part of its length that includes a lower section and an upper section. The lower section has a semi-elliptical, partial semi-elliptical, or partial semi-circular shape and the upper section has a pair of straight walls that are coupled to the lower section.

In another embodiment, a pumping channel is defined in a housing of a fuel pump. The pumping channel includes an arcuate recess defined in a surface of the housing. The arcuate recess has a length that extends from a first end to a second end. The second end is spaced from the first end. The arcuate recess has a cross-sectional shape along at least part of its length that includes a lower section and an upper section. The lower section has a semi-elliptical, partial semi-elliptical, or partial semi-circular shape and the upper section includes a pair of straight walls that are coupled to the lower section.

Brief Description of the Drawing Figures

Fig. 1 is a cross-sectional view of a prior art fuel pump;

Fig. 2 is a plan view of a cover of a fuel pump according to the invention, taken at a position similar to line 2-2 in Fig. 1;

Fig. 3 is a cross-sectional view of the cover, taken at line 3-3 in Fig. 2;

Fig. 4 is a cross-sectional view of the cover, taken at line 4-4 in Fig. 2;

Fig. 5 is a plan view of a body of the fuel pump according to the invention, taken at a position similar to line 5-5 in Fig. 1;

Fig. 6 is a partial cross-sectional view of one embodiment of a channel according to the invention, taken at a position similar to that encircled as 6-6 in Fig. 4;

Fig. 7 is a partial cross-sectional view of another embodiment of a channel according to the invention, taken at a position similar to that encircled as 6-6 in Fig. 4; and

Fig. 8 is a partial cross-sectional view of another embodiment of a channel according to the invention, taken at a position similar to that encircled as 6-6 in Fig. 4.

Detailed Description of the Invention

Fig. 1 depicts a cross-section of a prior art regenerative fuel pump 10 utilized in a vehicle to pump fuel from a fuel tank to the vehicle engine. The fuel pump 10 is configured to be positioned in a fuel tank and to pump fuel from the fuel tank upwardly through the fuel pump 10. The fuel pump 10 includes a pump housing 12, a pump inlet 14, a pump outlet 16, a motor 18, and an impeller 20, all of which are positioned about a longitudinal axis X-X of the pump 10. The pump housing includes a cover 22 and a body 24, among other parts. The cover 22 is positioned upstream from and adjacent to the impeller 20 while the body 24 is positioned downstream from and adjacent to the impeller 20. The cover 22 includes the fuel inlet 14 and the body 20 includes a fuel outlet 26. Fig. 2 depicts a plan view of the cover 22 including the fuel inlet 14 while Fig. 4 depicts a cross-sectional view showing the cover 22 with the fuel inlet 14. Fig. 5 depicts a plan view of the body 24 including the fuel outlet 26. The housing 12 serves as the outer housing for the fuel pump 10 and houses the cover 22, the body 24, the impeller 20, and other fuel pump parts.

The impeller 20 is used to move fuel through the fuel pump 10 and includes a disk-like body having a ring of vanes that are coupled to and extend outwardly from the outer periphery of the impeller. The impeller 20 is rotatable about the longitudinal axis X-X of the pump 10 about a shaft 28 and positioned between the cover 22 and the body 24 of the pump 10. The shaft 28 is driven by the electric motor 18. Power is supplied to the electric motor 18 through the vehicle's alternator or battery. The shaft 28 extends through the body 24 and the impeller disk 20, and seats in a central opening 30 defined in the cover 22. The cover 22 and body 24 are stationary within the pump housing 12.

The cover 22 and body 24 both include pumping channels 32, 34 that are circumferentially defined in the face surfaces 36, 38 of the cover 22 and body 24, respectively, about the longitudinal axis X-X. The face surface of the cover 22 is depicted in Fig. 2 and the face surface 38 of the body 24 is depicted in Fig. 5. The channels 32, 34 extend arcuately around the face surfaces 36, 38 of the cover 22 and body 24 near the outer periphery thereof. In a preferred embodiment, the channels 32, 34 follow a generally arcuate circular path that is adjacent the path of the impeller vanes. Other paths may also be utilized, if so desired. The channel 32 defined in the cover 22 is referred to herein as the cover channel 32 and the channel 34 defined in the body 24 is referred to herein as the body channel 34. The channels 32, 34, which are also known as pumping channels, are utilized to provide fuel to the impeller 20, which pumps the fuel through the pump 10.

Referring to Figs. 3-4 and 6-8, the cover and body channels 32, 34 have a cross-sectional shape that includes a lower section 40 and an upper section 42. The lower section 40 has a semi-elliptical shape 44, a partial semi-elliptical shape 46, or a partial semi-circular shape 48. The upper section 42 includes a pair of spaced straight walls 50 that extend from the lower section 40 to the face surface 36, 38 of the cover 22 or body 24.

Fig. 3 shows a cross-sectional view of the cover 22 at a first point X1 and a second point X2. A first cross-section is provided at the first point X1 and a second cross-section is provided at the second point X2. In a preferred embodiment, the first cross-section is different from the second cross-section. In particular, it is often desirable to ramp the channel 32, 34 from its first end 52 to its second end 54 (shown in Fig. 2), such that a height Y of the channel 32, 34 at the first point X1 is greater than a height Z of the channel 32, 34 at the second point X2. According to one embodiment of the invention, the ramping occurs by including an upper section 42 that differs in height between the first point X1 and the second point X2, while the lower sections 40 remain unchanged between the first point X1 and the second point X2.

In a preferred embodiment of the cover 22, shown in Fig. 3, the height of the upper section 42 at the first point X1 is greater than the height of the upper section 42 at the second point X2. The height of the upper section 42 preferably tapers along the length of the channel 32, 34, at least between points X1 and X2.

The straight walls 50 of the upper section 42 may be perpendicular to the face surface 36,38, as shown in Figs. 7 and 8, or may be angled relative to the face surface 36, 38, as shown in Fig. 6. When the straight wall surfaces 50 of the upper section 42 are angled, they are preferably angled at an angle α of about 5 degrees or less (e.g., but not limited to 3-5 degrees), such that the opposing walls 50 are both angled outwardly. This angle α is useful during the manufacturing process, where a completely perpendicular wall 50 may be difficult to achieve due to manufacturing tolerances.

The channels 32, 34 may also include a transition section 56, shown in Fig. 6. This transition section 56 is positioned between the upper section 42 and the lower section 40 and is useful in providing a smooth transition between the upper section 42 and the lower section

40 in order to reduce the likelihood of the formation of secondary vortices. The transition section 56 preferably includes a radiused wall 58 that is positioned between the upper and lower sections 42, 44 of the channel 32, 34. The radiused wall 58 may have a radius R, as shown in Fig. 6. The transition section 56 is most desirable when a partial semi-elliptical 46 or partial semi-circular 48 shape is utilized in the lower section 40. Radius R is determined based upon the shape of the partial semi-elliptical 46 or partial semi-circular 48 lower section 40 in order to provide a smooth transition between the upper section 42 and lower section 40.

As discussed in connection with Figs. 3-4 and 6-8, a preferred shape for the lower section 40 of the channels 32, 34 is semi-elliptical 44, partially semi-elliptical 46, or partially semi-circular 48. These shapes are preferred because they reduce or eliminate secondary vortices in the channels 32, 34. Fig. 6 shows a partially semi-elliptical 46 lower section 40 and Fig. 7 shows a semi-elliptical 44 lower section 40. Fig. 8 shows a partial semi-circular 48 lower section 40.

Fig. 6 identifies the elliptical parameters that define the shape of the lower section 40. The shape of the lower section 40 is defined by the following ellipsoidal equation:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

where

a = half the distance of the minor axis MI,

b = half the distance of the major axis MA, and

x and y are the axes of a Cartesian coordinate system centered on the center point P.

As is known in the field of geometry, the major axis MA of an ellipse extends along an axis from vertex V1, through center point P, to vertex V2. Length b extends from center point P to either of the vertices V1, V2. The foci F of the ellipse are a distance c from center point P along the major axis MA. Length a is half the distance of the minor axis MI and extends between the center point P and the co-vertex V3. A preferred range of values for length a is between about 0.8 and 2.5 mm, with a preferred length of about 1.0 mm. The preferred range of values for length b is between about 0.9 and 2.7 mm, with a preferred length of about 1.18 mm. Length c is calculated as a function of lengths a and b as follows:

$$c^2 = b^2 - a^2$$

Length c has a range that varies with the lengths a and b according to the above equation.

As seen in Fig. 6, the cross-section of the lower section 40 of the channel 32, 34 may be only a portion of a full semi-ellipse, also referred to herein as a partial semi-ellipse 46. A partial semi-ellipse 46 has a depth d, which is selected by the user. Preferably depth d is about 1mm, but has a range of about 0.5 to 2.5 mm. Depth d is preferably less than or equal to length a with a partial semi-elliptical shape 46. A semi-ellipse 44 is defined by the major axis MA and the ellipsoidal line having vertices V1 and V2, and co-vertex V3, as shown in Fig. 7. A semi-elliptical shape preferably has a depth d that equals length a.

Fig. 6 also shows in phantom a representation of a flattened bottom surface 60 of the partial semi-elliptical 46 embodiment. Any of the embodiments depicted herein may include this flattened bottom surface 60, which is sometimes desirable from a manufacturing perspective. Where a flattened bottom surface 60 is utilized with the lower section 40, the remainder of the lower section 40 utilizes a semi-elliptical shape 44, a partially semi-elliptical shape 46, or a partial semi-circular shape 48, as discussed herein.

In an alternative embodiment, shown in Fig. 8, a partial semi-circular cross-section may be utilized for the lower section of the channels 32, 34. The ellipsoid equation, when a = b, provides a circular shape. The terms partial semi-elliptical 46 and semi-elliptical 44, as used herein, exclude from their definition a semi-circle. However, the invention does include as an embodiment a partial semi-circular shape 48. This partial semi-circular cross-section 48 is defined in the channel 32, 34 such that the ends of the circular shape extend past the straight walls 50 of the upper section 42. Vertices V1 and V2 are positioned outside the channel 32, 34. In addition, depth d is less than length a. The shape of the partial semi-circular 48 cross-section can be defined by the elliptical equation, presented above, where a = b.

The cover channel 32, also preferably includes a vapor purge hole 62. The vapor purge hole 62, shown in Fig. 2, is utilized to allow any vapor that forms in the fuel, as it enters the cover channel 32, to exit before entering the impeller 20.

The cover 22 and body 24 may be formed of a cast material, such as aluminum or plastic. Plastic materials that may be utilized include thermosets, such as phenolic, or thermoplastics, such as PPS. Other types of materials may also be utilized, as known by those of skill in the art.

In forming the channels 32, 34 on the cover 22 and body 24, a preferred method is to cast the channels 32, 34 into the cover 22 and body 24 in a rough geometry. Then the particular dimensions of the channels 32, 34 may be machined during a milling process in order to refine the contours of the channels and to remove any burrs or imperfections.

While the invention has been described in connection with a longitudinal axis X-X of the pump 10, other axes, which are not necessarily aligned with the longitudinal axis X-X, may be utilized. In addition, while the channels 32, 34 have been discussed above mainly in the context of the cover 22, the body channel 34 has similar dimensions and characteristics as cover channel 32. The discussion above is meant to generically apply to both the cover channel 32 and the body channel 34, if so desired.

The lengths and depths discussed herein are for illustration purposes only. The actual lengths and depths of the parts utilized will depend on the size of the fuel pump 10, its impeller 20, and its various surfaces. Therefore, the invention is not to be limited to the lengths or depths discussed above. Furthermore, while the channels 32, 34 of the invention are discussed in the context of a fuel pump, the above description is also applicable to other types of pumps, the invention not being limited to use with a pump for pumping fuel.

While various features of the claimed invention are presented above, it should be understood that the features may be used singly or in any combination thereof. Therefore, the claimed invention is not to be limited to only the specific embodiments depicted herein.

Further, it should be understood that variations and modifications may occur to those skilled in the art to which the claimed invention pertains. The embodiments described herein are exemplary of the claimed invention. The disclosure may enable those skilled in the art to make and use embodiments having alternative elements that likewise correspond to the elements of the invention recited in the claims. The intended scope of the invention may thus include other embodiments that do not differ or that insubstantially differ from the literal language of the claims. The scope of the present invention is accordingly defined as set forth in the appended claims.